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CLIMATE and BUILDING

by

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DIRECTOR, DIVISION OF BUILDING RESEARCH

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CLIMATE and BUILDING

By R. F. LEGGET

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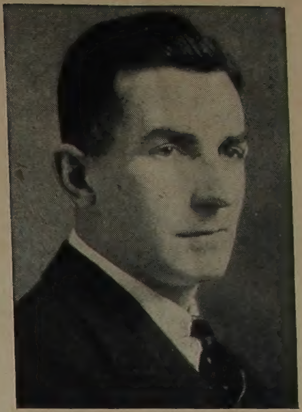
National Research Council



R. F. Legget

ONE OF THE MOST desirable characteristics of a title is brevity. "Climate and Building" meets this requirement even though the result is the combination of two terms, each of which is so broad that the resulting subject is one on which many volumes could be written. At the outset, therefore, it may usefully be explained that this title was chosen since it does describe in a very general way the content of this paper and because any accurate description of the subject to be treated would have necessitated a title far too long for convenience. The operation of building has been influenced by climate from the earliest days of history. Much building was initiated by man's need for protection against the elements. This inter-relation is common knowledge and well recognized. Tonight the attempt will be made to define this relationship with reference to modern building in Canada and to describe some initial steps which are being taken in an attempt to solve some of the many problems which climate causes in relation to building throughout the Dominion.

Considered even in this limited respect, the subject is still not new; it has been echoed in the writings of many inquirers. It was naturally touched upon by Francis Bacon who himself turned back through many centuries to restate the old question of Pompey when he asked Lucullus concerning his stately mansion—"Surely an excellent place for summer but how do you do in winter?" You may recall the answer which was given by the wise Lucullus. "Why do you not think me as wise as some fowl are, that change their abode towards the winter?" From the days of the early explorers of Canada, an alternative answer has here been sought in order to make Canadian buildings suitable for use both in summer and in winter, since so many of Canada's "wise fowl" go south in cold weather, whereas few citizens can do the same.

Brief consideration will show that the principal difference between building in Canada and building elsewhere is caused by the special climatic conditions which are experienced throughout this country. It appears, therefore, that Canada has its own contribution to make in this overall study if only because of the great variation in meteorological conditions throughout the Dominion. Same may recall Rudyard Kipling's possibly unfortunate reference to "Our Lady of the Snows", a reference which on hot, humid August days seems to be singularly restricted. Canadians generally appear today to be becoming slightly more conscious of the importance of climate to their economy. The excellent radio series of talks entitled "Clearing up the Weather" has assisted materially in developing this public appreciation. It is significant that the talk on Sunday evening last dealt in a singularly interesting manner with Weather and the Building of a House.

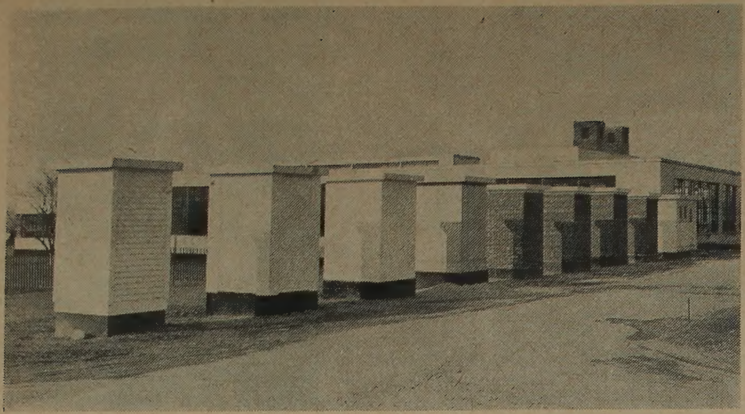
The climate of Canada has been made the subject of one of the interesting monthly news letters published by one of the leading chartered banks of Canada. (1) In this little publication it is pointed out that all parts of Canada (even including Victoria, B.C.) have experienced temperatures below 0°F. within the period of recorded observations and have been correspondingly subjected to summer temperatures in excess of 95°F. This is a salutory reminder that the climate of Canada must be one of the most extreme for any major country. This one fact alone would suggest that attention should be devoted within the Dominion to the influence of climate on building and to possible improvements which can be made to aid human comfort. It is to report upon initial moves in this direction that this paper is presented.

The fundamental effect of climate on building design and construction is one of the basic problems under study by Canada's Building Research Division of N.R.C. In this paper originally presented before the Canadian Branch of the Royal Meteorological Society at Toronto, Division Director Legget reports on the start of this continuing project and describes various aspects of studies now under way.—Editor

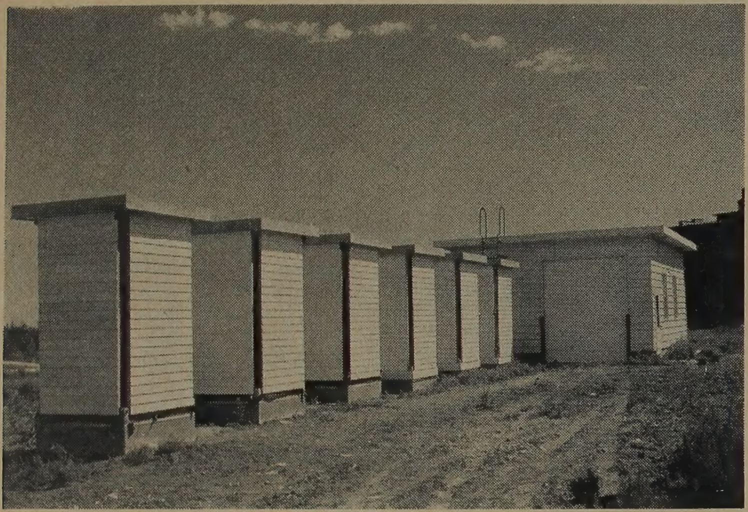
It is usual for an engineer to define his terms at the outset of any important statement. It would naturally be presumptuous to attempt to define climate to such an audience as this. The hope may therefore be expressed that the term will not be found to be misused in what must be a somewhat general and mundane discussion. The term building, on the other hand, is used in the broadest way possible, as it is used in the title of the Division of Building Research, including all constructional activities in this country and comprising basic design, selection of materials and actual construction operations.

Recent Interest in the U.S.A.

As a useful preliminary to describing special Canadian problems related to climate and building, brief reference may be made to the surprising development of interest in this subject within the last year or two in the United States of America. This is one of many constructive results of the recent war. Wartime studies of environmental control carried out through the Quartermaster's Corps of the American Army, pointed the need for an accurate delineation of limiting climatic factors. Some of



Test huts as erected at Ottawa by the Division of Building Research, N.R.C., to study effect of climate on buildings. Under study is heat loss and relative humidity, with various types of exterior walls.



Prairie conditions can be studied by these test huts at Saskatoon, Sask. Another is under construction in the north at Churchill, Manitoba. A complete instrumentation system provides desired data.

those who worked on this wartime project were invited to apply their special knowledge to civilian building problems by the Editor of one of those excellently produced, somewhat popular magazines which are so striking a feature of the current American scene. The Editor of "House Beautiful" initiated what has been called a "crusade" for improvements in climatic control in housing in 1948. As a result, there have appeared in regular issues of this magazine a succession of articles describing the limiting climatic factors in various regions of the United States and the application of this information to domestic architecture not exactly in the low-cost category (2). The project has attracted much attention. The information has been published in an amended form by the American Institute of Architects (3).

The crusade has been considered a notable contribution to general understanding of the importance of climate in relation even to the restricted field of house design and construction. Although those responsible for this project have dealt with it strictly in terms of current practice, they would probably be the last to suggest that their project was entirely new. They may have adopted as their initial thought an interesting statement of Francis Bacon which might even be thought to be a forecast of modern architecture:—"Cast it (the house) also that you may have rooms both for summer and winter; shady for summer and warm for winter. You shall have sometimes houses so full of glass that one can not tell where to become to be out of the sun or cold."

The diagrams which Dr. Siple and his colleagues have produced are extremely clear and easy to use. They follow in a long tradition of which possibly the most interesting contribution has been the hythergraphs which have so long been a feature of publications of Professor Griffith Taylor.

Partially as a result of this project of "House Beautiful", a conference was held in Washington on 11th and 12th of January, 1950, under the auspices of the American National Research Council, to consider "Weather and the Building Industry". This was the first conference to be organized by the Building Research Advisory Board of the U.S.A. This Board is not an active laboratory research organization but has as one of its principal functions the convening of research correlation conferences. The first meeting was called to consider climatological research and its effect on building design, construction, materials and equipment. The meeting was attended by two hundred and fifty including several Canadian and two South Africans. During the course of a day and a half many papers were presented, some of them recapitulations of the "House Beautiful" work, others dealing with various aspects of climate with special reference to human comfort and domestic architecture. The papers have been published in convenient form as a volume of one hundred and sixty pages. At the end of this is a bibliography of about two hundred items which in itself shows what wide attention is now being paid to climate in relation to building. (4).

Brief reference must also be made to the outstanding work of the American Society of Heating and Ventilating Engineers which, through its research organization, has played a leading part in the application of climatic studies particularly to the problems of heating and ventilating buildings. Publications of this Society are well known to all who work in this field and are highly regarded for their useful and practical character.

Recent Interest in Other Countries

Recent developments in building research are not confined to North America. Passing reference must therefore be made to notable work which is being carried out through building research organizations in other countries, in particular those in Australia and South Africa. Both of these countries now have special teams of workers engaged in investigating some of the special problems which the relatively hot climates of the two countries create in relation to building and in particular to low cost housing. In Australia a particularly interesting development has been the use of small scale models of houses for the investigation of the thermal properties (in relation to the weather) of full size structures. Time will not permit more than this brief reference but it is appropriate that note should be made of this work on the other side of the world and also of corresponding studies on a somewhat more restricted scale in Holland and in Sweden.

Building Research in Canada

Against this background so roughly sketched, consideration may now be given to the attention which is being devoted in Canada to building problems. Almost from the start of regular building activities in this country there have been pioneer architects, engineers and contractors who have not been content to accept without question methods and designs which did not prove to be entirely suitable. These men are the pioneers of building research in Canada. Fortunately, many such men are still with us. Individual efforts will always be a major stimulus to advance in building technology. The construction industry, however, has now become so large and so important to the economy of Canada that something more than these individual efforts has been seen to be necessary for some time. The war delayed an active start at organized building research but in 1947 the National Research Council finally set up its new Division of Building Research as a result of many years' consideration.

The main function of the Division is to provide a research service to the construction industry of Canada. It has also to serve as the research wing for Central Mortgage and Housing Corporation. From its start, therefore, it has been particularly concerned with problems of house construction. The Division is not concerned with research into architectural or community planning but it does have as one of its special responsibilities work in connection with the National Building Code of Canada. Its task, therefore is a major one. The difficulty of starting this at a time when the level of construction in Canada is at an all-time high, has been and still is a great challenge.

Accordingly, careful thought has had to be given to those branches of building research which are peculiar to Canada and which must be studied in this country, leaving to building research organizations in other countries problems which are not dependent on local conditions. The two major local determinants are the geology of Canada and its climate. If thought be given to these controlling factors it may be appreciated that the Division has been able to consider its immediate and major tasks under five group headings, in addition to its work on the National Building Code. These are foundation and soil conditions (dependent generally on geology), snow and ice problems, fire research, the special problems of building in the North and—last but most important of all—the whole problem of the enclosure of buildings with reference to the climate of Canada. It will be seen that four of these five groups are determined primarily by climatic factors while even the fifth one is influenced by them to some degree.

Climate, therefore, has been a matter of continued study from the very first days of the Division. It was recognized at a very early date that if the work of the Division was to be carried out efficiently climatic factors must always be considered, climatology being regarded as probably the most important of the associated field of scientific inquiry. As will shortly be seen, the Division has been privileged to co-operate already with the Meteorological Division of the Department of Transport*. The writer has benefited immeasurably by his continued talks with its Controller and members of his staff. If this paper suggests that the Division is starting off its work on the right lines with respect to climatology, this is in large measure due to this very happy and continually developing liaison.

Special Canadian Problems

Up to this point, general statements only have been made in an attempt to show the close correlation of climatic conditions and building problems. It will probably be helpful if a complete change in procedure is now made and some typical specific problems which relate climate with building are outlined. The following, therefore, constitute a collection of problems which are typical of the many which await solution even with references to building in Canada.

(a) Construction and Terrain Problems

A major problem relating to building in Canada which is very evidently affected by weather is the general question of construction during winter periods. There was a time when construction throughout the Dominion almost ceased when once the snow had come. Over the years, practice has changed. There are now many building jobs which continue without stop through the twelve months of the year. The carrying out of construction under winter conditions involves extra cost and difficulty, the extra cost being a singularly difficult thing to calculate or to estimate in advance. An overall economic study of winter construction with a view to defining the limits within which it is economical, is therefore a major task in the field of building research. Correspondingly, a most useful guide to winter construction will be a statistical statement of limiting winter weather conditions for any particular locality since only on the basis of such information can accurate advance estimates usefully be made.

Construction which is carried out on or near rivers is often dependent on the time of "spring breakup" as are so many other outside operations in the more isolated parts of this country. Some attempts have been made to calculate the date on which the ice on rivers and lakes will first start to move but the solution to this very important practical problem has not yet been obtained. It constitutes a fascinating piece of climatological research intimately associated with building. Mention of ice is a reminder that the formation of ice on lakes, its thickness and its bearing capacity are similar outside problems on which much work must yet be done and which cannot be adequately investigated without full knowledge of related climatic conditions. Correspondingly, the most complex problem of the pressure exerted by sheets of ice, on structures such as dams now currently under investigation both in Canada and the United States must be correlated with accurate and relevant climatic data. (5)

Since Canada is covered with snow throughout a portion of each winter, knowledge of the properties of snow throughout this country is essential for many reasons. These include a number related to construction and operations and even to building, with reference to such items as the snow loads upon roofs.

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*To avoid confusion, the Meteorological Division will hereinafter be called the "Service", the word "Division" applying to the N.R.C. Division of Building Research.

Some progress has been made in the study of snow under the auspices of the Associated Committee on Soil and Snow Mechanics of the National Research Council (which is linked with the Division of Building Research). For the past four years, detailed observations of all the scientific properties of snow have been made at twelve locations across this country. All but two sets of observations have been made by members of the staff of the Meteorological Service whose most co-operative and skilled assistance has been widely appreciated. Results of these records have been summarized but their complete analysis awaits detailed climatological study. (6) The survey is continuing and with similar work will probably be a continuing part of such outside research work, always carried on in relation to corresponding weather records.

(b) The National Building Code

Building codes are local ordinances specifying minimum standards of building which must be followed in the interests of public safety from the points of view of fire prevention, public health and structural sufficiency. There have been some building regulations in operation in Canada for at least one hundred and fifty years. Only in recent years has their importance become so widespread as is now the case. Some years ago in order to assist small municipalities the National Research Council, jointly with the Department of Finance arranged for the preparation of an advisory National Building Code. This volume of over four hundred pages was published in 1941. (7)

The Code is a notable document, having been described in an official British publication as the best code existent when it was published. It is in need of a revision and this work has now been started. In order to serve national needs, the National Building Code must naturally take into account the varied climate of Canada. Accordingly, in the new arrangement which has been developed for the code, a separate section has been allocated to Climate. It is planned in this section to delineate certain climatic zones into which the country can be divided with reference to such basic building factors as thermal insulation, wind loads and snow loads. When this task has been done, minimum standards for this and similar factors can be laid down for each zone so that the one document will serve more satisfactorily than at present as a code for local building regulations in all parts of the Dominion.

Such climatic zoning is not a new thing but it is believed that this effort in Canada will be the first attempt to include such zones in a building regulation. The task will not be an easy one and will involve the study of an immense amount of climatological information. It is therefore a pleasure to be able to announce that the Chairman of the Committee responsible for this part of the revised National Building Code will be Mr. C. C. Boughner, Head of the Climatological Section of the Meteorologocial Service of Canada.

(c) Design Factors

Building standards such as the National Building Code merely specify minimum standards which must be adhered to in order to insure that building in Canadian municipalities meets certain basic requirements. Standards for ordinary building practice are usually better than those laid down in building codes. Local information is always necessary for the design of such building features as heating and ventilating. As has been mentioned, the American Society of Heating and Ventilating Engineers has for some years made useful contributions to this part of building design. (8) There is great need for the extension of this information and the development of corresponding information for parts of Canada not yet covered in publications such as those of the Society mentioned. It is necessary in all such cases to know the limiting climatic conditions. This involves careful statistical study of all available climatic data.

There is much talk in these days of the use of solar energy for the heating of buildings. Some studies have been made in the United States. It is necessary and desirable that these studies should be extended to cover Canadian conditions even though the prospects of the wide use of solar radiation do not appear to be economically encouraging. Some work in this field has been started at the University of Toronto. Professor E. H. Gowan, of the University of Alberta, has for some years made a special study of the measurement of solar radiation. One of the first co-operative endeavours of the National Research Council and the Meteorological Service was the purchase of a number of recording pyrheliometers. These have been in operation for some time so that factual information is being accumulated which can form the basis of another most important piece of climatological research in relation to building.

Other building design problems relate to temperatures and heat flow beneath the surface of the ground rather than upon it. The depth of buried pipes, heat losses from building, frost action in soils—these and many associated problems are linked by the basic variations in soil temperature with increasing depth throughout the year. These variations are determined by thermal flow from the centre of the earth and by the local climate. The Division has been engaged for some time in a long term study of soil temperature variation. It has been privileged to co-operate in this work also with the Meteorological Service following the start of work in the grounds of the Meteorological office in Toronto, when the writer was on the staff of the University of Toronto. (9)

(d) The Weathering of Building Materials

This branch of building research work is perhaps more obviously linked with climate than some other aspects which are being mentioned. Clearly the weathering of building materials which are exposed to the atmosphere is dependent to a large extent upon the climate to which they are exposed. Accordingly, it will be essential to correlate all work in this field which the Division will do with meteorological records. This is already important as the Division is developing six outside corrosion test sites at specially selected locations across this country, the operation of which can only be effective if relevant meteorological records are taken from the start of their operation.

This branch of work brings up one of the more interesting detailed climatic problems in relation to building, this being the significance of the number of cycles of freezing and thawing to which building materials are exposed. A standard test for building materials is to subject them to a number of artificially induced cycles of this kind. The significance of this test will only fully be appreciated when test results have been correlated with actual freeze-thaw cycles in nature. The problem is a complex one but quite clearly is one of special importance in Canada as is also the associated problem caused by sudden rises and falls in temperature and their effect upon building materials.

(e) Performance of Building

Problems which have so far been suggested might almost seem to have exhausted the field of common interest between climatology and building research. They are, however, merely an indication of many such problems. In importance they probably are far surpassed by another group of problems relating to the actual performance of buildings. By this term is meant generally the heat and water vapour loss through buildings throughout the year when considered in relation to the sources of heating or cooling and local climatic conditions, always with the comfort of the occupants as the main controlling factor, and basic economics as a major determinant. It is a vast subject, but a start has been made at its study by the Division following a most careful survey of possible approaches to the problem.

The use of ordinary houses is an obvious solution. It is not a very satisfactory one since the performance of any occupied house is dependent to such a large degree upon the habits of the occupants. Accordingly, the Division has developed at Saskatoon and at Ottawa installations which consist essentially of concrete tunnels, over the roof of which can be erected sample test huts, each measuring about four feet square and eight feet high. At Saskatoon six huts have been erected and at Ottawa nine. In each location there is one standard hut which is now being reproduced again at Churchill, Manitoba, and which it is hoped may be duplicated at State College, Pennsylvania. At each of the test locations, meteorological records are already being taken. The test huts will be heated and humidified throughout the winter and their performance most carefully measured by means of a complete system of instrumentation.

It is hoped that in the course of a few years the performance of the standard huts can be so correlated with the local climatic data that some agreement in correlation between four test locations will be found. If this does prove to be the case, then it will be possible to take the results of tests with the other test huts at Saskatoon and at Ottawa and apply them to any location in Canada provided only that the limiting local climatic data are known. This is the hope of the Division. It is a programme which is submitted to this expert audience for their comment and most careful criticism.

Many incidental problems can be studied through the medium of these test huts of which the most important is the vital question of wind chill on structures. This is a matter which has been extensively studied in recent years in connection with human comfort. it is thought of tthe Division that corresponding effort should be put into a study of the effect of wind upon the performance of buildings. Evidence has already been accumulated which suggests that the effect of wind is possibly more serious than is usually imagined, even with well-insulated houses.

A corresponding subsidiary study will be an investigation of the shielding effect of the test huts one upon the other. They are located relatively close together since the aeronautical authorities consulted could not state what was the minimum required spacing in order to avoid any interference with reference to wind conditions. This tury will be made by means of portable anemometers through comparison of records so obtained and those from a fixed anemometer adjacent to the test huts. This will constitute a small study in the field of micro-climatology.

The location of the test huts at Ottawa is going to provide an even more interesting study in micro-climatology. A small meteorological station has been set up adjacent to the huts and this is now in operation. It is located less than a mile from the main station of the Meteorological Service at the Rockcliffe Airport, which is somewhat lower in elevation and is shielded by rising ground. Continuing comparison of the results of these two meteorological stations should eventually provide data of significance and great use.

Building Research and Climate

These references to micro-climatic studies constitute a suitable point at which to stop the recording of building research projects with which climate is intimately associated already envisaged by the Division. The list might seem to be developing into almost a catalogue. It will, however, serve to confirm the importance of climate in relation to building research in Canada, as outlined at the beginning of this paper.

The concluding references will show that many of these problems will constitute a "two-way operation" in that many of them should provide information which will be of use from the purely climatological standpoint, in addition to answering building problems. It is in this way that the Division is looking forward to the steady expansion of studies of weather in relation to its work.

It is appreciated that in order to carry out a few of the projects which have been listed, the statistical study of a tremendous mass of meteorological records will be necessary. This will not be surpising to many in this audience. It may be useful to record that at the Washington meeting it was mentioned that the study of five and a half million single observations had been necessary for the preparation of one five-year climatic table presented by Dr. Siple. The United States Weather Service now have a "deck" of almost one hundred million punched cards recording meteorological observations. Even these represent only a part of the records available through this great Service.

In Canada, despite the hopes and plans of the Controller of the Meteorological Service and his staff, practically no progress has yet been made with regard to even the start of putting Canadian meteorological records on punched cards.* This purely mechanical operation is a basic requirement for all modern use of climatic records. The Division therefore hopes that the urgency of its own needs for climatic data may assist the Meteorological Service with the tremendous task which lies ahead of it in developing its own punched card records—not only in connection with building problems but for many other requirements throughout the entire Canadian economy.

It may be asked how the Division proposes to use this climatic information when it is available. It is therefore a pleasure to announce that the Division does not propose to employ climatologists on its own staff but rather looks forward with confident anticipation to the culmination of its preliminary liaison with the Meteorological Service by having climatologists on the staff of the Service, seconded to work with it for their full time on building research problems.

The wisdom of this course will be apparent to all who appreciate the desirability of scientists being kept in close associatin with fellow scientists in their own field. The re-

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*It was a very great pleasure to hear, in the discussion of this paper, that the first Canadian punched card climatic record was made on 17 October, 1950. It is hoped that this is but the beginning of a continuing operation.

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cords which the Division wishes to use are in the keeping of the Meteorological Service. This is a further reason for the development which has been planned in full co-operation with the Controller of the Meteorological Service who has been most helpful in this matter, as in so many others.

Conclusion

There may have been some who wondered at the outset what connection there could be to climate and building and, in particular, why the Division of Building Research of the National Research Council had any special interest in climatic matters. It is hoped that such natural questioning has now been fully answered. Building research in Canada can only go forward to meet the great challenge which lies ahead of it if it plans to work with full appreciation of the significance of climate in all its outside studies and if it is armed with the necesary factual information on Canada's varied climate which is so essential for the full understanding of the problems it will meet.

This information is available in the records of the Meteorological Service. It was a favourite saying of the late Dr. Isiah Bowman that the climatological data in the files of the United States Weather Bureau represented more wealth than all the gold in the Klondike. The same statement might be made of the records available here in Toronto which the Meteorological Service have accumulated so faithfully through the years in which they are so anxious to put to full public service. If the insistent demands of building research do nothing else in relation to climatology, it is hoped that they may at least assist our distinguished Meteorological Service in the start of the processing and development of its great store of climatological records for the benefit of the whole of this wide Dominion.

There appear to be some who think that the Meteorological Service is merely a means for obtaining information on the weather from day to day, in order to make flying possible and safe. Administration of the Service through the Department of Transport may appear to lend support to this view. The vital importance of meteorological records to both civil and military aviation can not be denied. Daily weather records, however, have a variety of other uses, notably in connection with farming and road transport, some of which may eventually assume unsuspected importance. Studies of climate, however, involve the use not of current daily records but of the accumulation of such records, for as long a period as possible. It is suggested, with great respect, that Canadians in general have not yet begun to realize the potential value of the climatic records now in keeping of the Meteorological Service. Probably for this reason, the Service has not been able to begin to process its store of records so that they can effectively be put to public use.

The Division therefore counts it a rare privilege to be associated with the Service in seeking the use of its climatic records, hoping that the servicing of its needs will result in wide public knowledge and use of these invaluable data. It is a singularly happy thing that the youngest of Canada's scientific and research services should thus be working in harness with one of the oldest and most distinguished of the Dominion's scientific and research organizations—for such the Meteorological Service assuredly is. It is greatly to be hoped that through the continuing association of these two public organizations real contributions not only to building research but also to climatology may be made which will be of benefit not only in Canada but for all those who have to meet similar problems connected with both climate and building.

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